OPPORTUNITIES TO ENHANCE AND MAINTAIN THE TALLGRASS PRAIRIE ECOSYSTEM WITHIN THE BOUNDARIES OF TALLGRASS PRAIRIE NATIONAL PRESERVE

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Opportunities to Enhance and Maintain the Tallgrass Prairie Ecosystem Within the Boundaries of Tallgrass Prairie National Preserve

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FOREWORD

Often our images of the prairie are those of a vast open landscape with unending sky and unbounded land with great herds of bison and populated by native peoples leading what some have come to see as an idyllic life. This landscape — shaped by the effects of fire, grazing, weather, geology, and human activities — was viewed by most early Euroamerican settlers as a "Great American Desert," something to be hurried through en route to the Golden West. Those who remained spent much of their lives trying to find ways to create boundaries for what had been boundless.

The tallgrass prairie once spread across some 60 million hectares and extended from southern Texas to southern Manitoba. While estimates vary, it is acknowledged that only a small percentage of it now remains; perhaps 1 to 4 percent. These are largely areas of steep terrain or rocky soils or both, areas generally unsuitable for crop production. Today, the prairie ecosystem with its many interwoven strands of life and processes is seen as perhaps the most threatened ecosystem in North America.

Various efforts to establish some form of national tallgrass prairie preserve over the last 40 to 50 years were largely unsuccessful. However, on November 12, 1996, President Clinton approved H.R. 4236, the Omnibus Parks and Public Lands Management Act of 1996 (Public Law 104-333). Title X, Subtitle A of the act authorizes Tallgrass Prairie National Preserve as a unit of the National Park System. The 10,894-acre preserve was established "to provide for the preservation, restoration, and interpretation of the Spring Hill Ranch area of the Flint Hills of Kansas, for the benefit and enjoyment of present and future generations."

The National Park Trust, a national nonprofit land conservancy organization, owns the preserve. This has created a unique partnership. The Federal government can acquire only by donation up to 180 acres of real property within the boundaries of the preserve. With the consent of the landowner, the remaining private property can be administered through a cooperative agreement and within the provisions of law generally applicable to units of the National Park System. These provisions include regulations issued by the Secretary of the Interior that provide for the proper use, management, and protection of persons, property, and natural and cultural resources. With the consent of the landowner, construction, reconstruction, rehabilitation, or development of essential buildings, structures, and related facilities on private property may also occur.

The authorizing legislation directs the Secretary of the Interior to develop a general management plan for the preserve. The general management plan will provide a vision for the future of the preserve and a practical framework for decision making. It will help identify the strategies, programs, actions, and support facilities necessary to manage the visiting public and to protect the preserve's resources in accordance with the authorizing legislation and all other applicable laws and policy. The plan will not provide specific facility designs, resolve all issues, or guarantee funding for implementation. Instead, it will describe the general direction the National Park Service intends to follow, with the cooperation of the National Park Trust, in managing the preserve for the next 10 to 15 years.

The legislation further requires the general management plan to provide for "maintaining and enhancing the tallgrass prairie within the boundaries of the Preserve." In addition, the first purpose of the national preserve given by the act is "to preserve, protect, and interpret for the public an example of a tallgrass prairie ecosystem on the Spring Hill ranch, located in the Flint Hills of Kansas."

A team of highly qualified National Park Service employees with the appropriate professional backgrounds and experiences was assembled to develop the general management plan. One of the first issues identified by the team was the need to reach a consensus on what "maintain" and "enhance" mean as they relate to tallgrass prairies in general and to the preserve specifically.

The team has a firm understanding of the national significance of the resources, both natural and cultural, found within the boundaries of the preserve, that clearly justify its inclusion in the National Park System. They also keep before them the need and importance of developing the general management plan within the vision set forth in the authorizing legislation. The team chose the panel concept as a means of receiving scientific, technical, and scholarly advice and as a way to obtain a broad consensus on topics and issues that would be difficult to get at without long and expensive studies. This panel was composed of people recognized for their contributions to our knowledge and understanding of prairie ecosystems.

The panel's conclusions and recommendations, along with other information and input from public participation, will be used by the team to develop a range of practical and reasonable alternatives for the long-term management of the preserve, the preservation of its resources, and the development of public service for its visitors. The team's objective is to develop and recommend a plan that will, in the words of the legislation, "conserve the scenery, natural and historic objects and wildlife of the ranch; and provide for the enjoyment of the ranch in such a manner and by such means as will leave the scenery, natural and historic objects, and wildlife unimpaired for the enjoyment of future generations."

> A human being is part of a whole, called by us the 'Universe,' a part limited in time and space. He experiences himself, his thoughts and feelings, as something separated from the rest – a kind of optical delusion of his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires and to affection for a few persons nearest us. Our task must be to free ourselves from this prison by widening our circles of compassion to embrace all living creatures and the whole of nature in its beauty.
>
> Albert Einstein

John Neal, Team Captain
General Management Planning Team
for Tallgrass Prairie National Preserve, Midwest Region

INTRODUCTION

Tallgrass Prairie National Preserve is the first National Park Service area established specifically for the preservation, protection, and interpretation of a tallgrass prairie ecosystem. Authorized by Congress in 1996, Tallgrass Prairie National Preserve is a 10,894-acre site located in the heart of the Flint Hills in Chase County, Kansas. The preserve is dominated by virgin tallgrass prairie on hills and in valleys, but it also includes creeks, intermittent streams, and springs and seeps. Prior to its authorization as a national preserve, the area had been a farm or active cattle ranch for more than the last 100 years. Observable features related to the area's historic uses include buildings, fences, corrals, and stock ponds, among other things.

The authorizing legislation is unique in that the National Park Service (NPS) will own only up to 180 acres of the preserve. The rest of the property will continue to be owned by the National Park Trust, a nonprofit land conservancy organization, but the property will be managed by the NPS through a cooperative agreement. The legislation directs the NPS to develop a general management plan (GMP) by September 30, 2000, which will serve as the basis for management and operations of the preserve for the next 10 to 15 years. The legislation directs that the GMP shall provide for the maintenance and enhancement of the tallgrass prairie within the preserve. Consistent with the NPS Organic Act of 1916 and the authorizing legislation for Tallgrass Prairie National Preserve, to "maintain and enhance" is interpreted to mean that management will sustain and increase biodiversity.

An NPS team was formed to develop the GMP. The team has gathered information on the site's history and its cultural and natural resources. They are also soliciting public input through a variety of formats. One of the primary pieces of information sought by the planning team is how various management options may effect biodiversity. A major goal is to understand how the preserve can be managed to increase the biodiversity of the tallgrass prairie.

Although limited site-specific information has been gathered on the biological resources of Tallgrass Prairie National Preserve (TAPR), much research has been conducted at similar locations on the effects of different fire and grazing regimes on biodiversity and productivity in a tallgrass prairie ecosystem. For example, the nearby Konza Prairie Research Natural Area (KPRNA), operated by Kansas State University, has conducted 25 years of research with findings directly applicable to the preserve.

Thus, the planning team asked the NPS Midwest Region's Associate Director for Natural Resource Stewardship and Science to assemble a team of prairie and range scientists to provide their expert opinions on the following issues:

(1) the potential biodiversity of the tallgrass prairie ecosystem in the Flint Hills and at TAPR;

(2) the definition of high-quality range in the Flint Hills;

(3) how fire and grazing can be manipulated to increase biodiversity of the tallgrass prairie ecosystem;

(4) specific management scenarios for TAPR that will enhance tallgrass prairie;

(5) Inventory, monitoring, and research needs; and,

(6) restoration of cultivated and nonnative grasslands in the floodplain of Fox Creek and restoration of other impacted riparian area within the boundaries of the preserve.

Each panel member was approached on the basis of publication record and experience with tallgrass prairie ecosystems. Each member contributed to the mix of views and expertise (e.g., range and conservation ecology, plant and animal, and terrestrial and aquatic expertise). The facilitated workshop was held September 7–10, 1997, at KPRNA and Kansas State University. The following five sections of this report summarize the consensus and recommendations of the workshop participants. The invited workshop participants' credentials can be found in the appendix (pp. 27ff).

The next section of the report describes the general character of tallgrass prairie and its potential biodiversity. It also describes the effects of different grazing and fire regimes on diversity and the specific potential of TAPR. Following this, a short section specifically addresses the predicted effects of the current management regime of annual spring burns and double stock grazing from May through July.

The largest section of this report, Management Recommendations, covers a variety of topics. The group feels strongly that the NPS needs to manage the preserve with full knowledge of its history, its current make-up, and its potential. Accordingly, the *Baseline Inventory* and *Monitoring* subsections are dedicated to recommendations for baseline inventories and for the design of monitoring programs to detect biotic trends in time and space and to evaluate the effects of management regimes on biodiversity. The next subsection, *Upland Habitats*, provides recommendations on how fire and grazing can be manipulated in the uplands to increase biodiversity. *Riparian and Aquatic Habitats* describes and provides management recommendations for the floodplain and aquatic habitats found within the preserve. Recommendations on other issues not addressed above, including development within and outside the park, exotic species, erosion, and hunting and fishing, are discussed under *Other Management Issues.*

The final and concluding section summarizes the findings and recommendations of the group and presents a conceptual spatial model for management of the preserve.

POTENTIAL BIODIVERSITY AND CHARACTERISTICS OF THE TALLGRASS PRAIRIE ECOSYSTEM

A tallgrass prairie ecosystem is dynamic and diverse. The biodiversity, function, and structure of this ecosystem are strongly controlled by key natural disturbances including periodic fire, grazing by large mammals, and an annually variable climate (Knapp et al. 1998a). The native Flint Hills tallgrass prairie landscape is characterized by its heterogeneity, as the interaction of fire, grazing, and climate create a shifting mosaic of patches in various stages of impact and recovery from fires, grazing, drought, and flood.

Fire is essential to the maintenance of a functioning tallgrass prairie ecosystem. Without periodic fire, a gradual replacement of prairie species with woodland species occurs. Historically, this system experienced highly variable fire frequency and seasonality, with an average long-term fire return interval of 3-5 years (Bragg 1995). Frequent (annual) fires reduce heterogeneity and biodiversity (Figure 1) relative to periodic burning (Collins 1992), and grazing enhances biodiversity (Figure 2) relative to ungrazed prairie (Collins and Barber 1985; Hartnett et al. 1996). The interaction of periodic (and seasonally variable) fire and grazing optimizes native biodiversity in this system (Collins and Barber 1985, Collins 1987, 1992). Historically, spatially variable grazing was driven by animal responses to the patchy forage quality and productivity generated by vegetation responses to variable fire and precipitation regimes (Hansen 1984; Coughenour 1991; Vinton et al. 1993). The net result was a dynamic mosaic pattern across the landscape in which few patches were burned or grazed within the native tallgrass prairie landscape at the same time every year.

The tallgrass prairie mosaic includes a diverse mixture of warm-season perennial tallgrasses, cool-season graminoids, composites, legumes, and other forbs. Woody species such as New Jersey tea (*Ceanothus herbaceus*), dogwood (*Cornus drummondii*), and aromatic sumac (*Rhus aromatica*) are all integral to the tallgrass prairie plant community, although in limited abundance. The heterogeneous mixture of grasses, forbs, and shrubs provide the appropriate vegetation structure that can maintain a diverse community of animals (insects and other invertebrates, reptiles, birds, and mammals). Terrestrial invertebrate diversity is closely correlated with plant taxonomic and structural diversity. Plant and animal community responses to fire, grazing, and historic changes in management are expressed primarily as changes in relative abundance, rather than absolute loss or gain of species. The tallgrass prairie biota is evolutionarily young, composed mostly of species with their centers of origin elsewhere, and thus rare endemic terrestrial taxa are few (Freeman 1998).

Native ungulates historically were a key component of Great Plains grasslands and played a central functional role in these ecosystems. The activities of the myriad other above- and below-ground animals also contribute significantly to the structural diversity and heterogeneity of the prairie. For subhumid tallgrass biomes such as tallgrass prairie, total herbivore consumption (including consumption by large ungulates, insects, rodents, etc.) can be as high as 40 percent of aboveground biomass (Pieper 1983). These large native ungulates are adapted to interactions with the landscape and vegetation resources at large spatial scales. Thus, adequately representing the spatial-temporal characteristics of large free-roaming herds and pre-settlement fire patterns requires a large area, perhaps 100,000 acres or more. A functional native herbivore population approximating natural grazing patterns, social behavior, and interactions with fire also is area-dependent and requires a minimum area of several thousand acres. Although replacement of native with introduced domestic ungulates in the Great Plains provided a continuation of grazing processes, the spatial and temporal patterns of grazing and its impacts differ.

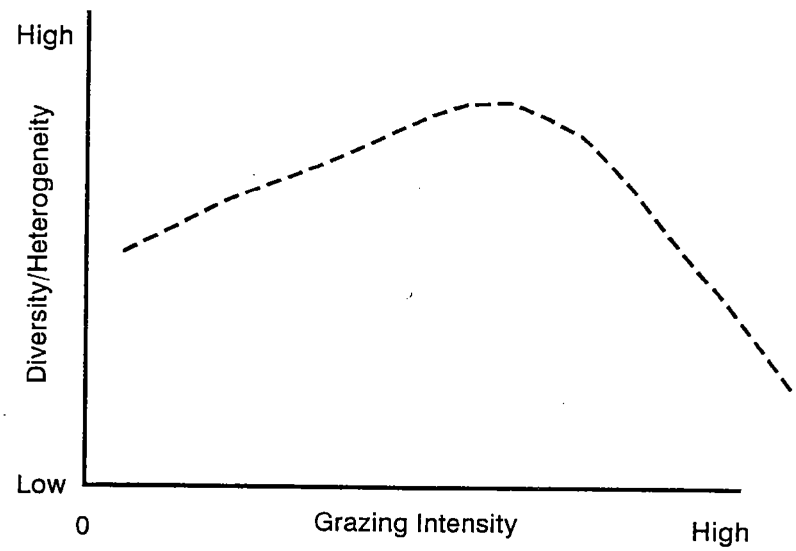


Figure 1. Effects of grazing intensity on plant species diversity and landscape scale vegetation heterogeneity in the tallgrass prairie.

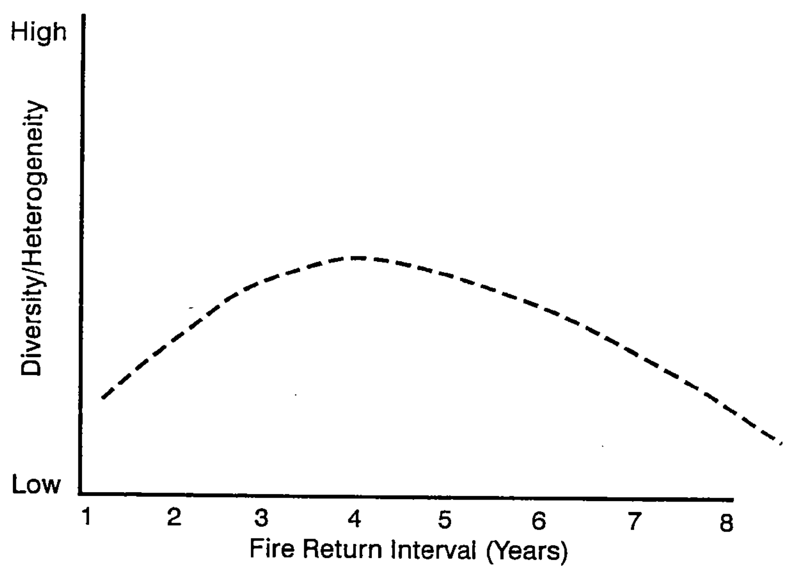


Figure 2. Effects of fire frequency on plant species diversity and landscape level vegetation heterogeneity in the tallgrass prairie.

Compared to domestic cattle, native ungulate grazers have different foraging patterns and non-grazing behaviors (e.g., wallowing), resulting in higher spatial heterogeneity and biodiversity under similar stocking rates (Hartnett et al. 1996; Plumb and Dodd 1993). In contrast, cattle are better adapted to smaller, subdivided, land units and are thus more appropriate as a management tool for small (dozens to hundreds of acres) pasture units (Plumb and Dodd 1993; Hartnett et al. 1997).

Given the importance of large spatial scales to the dynamics of the native prairie landscape, it should be emphasized that TAPR's area limitations will impose constraints and that the preserve should not be viewed as an island. Rather, it will be strongly influenced by land use and management patterns on adjacent tracts. Similarly, adequate representation of historical patterns of prairie fires requires a large area. Burned patches in the landscape mosaic were also likely on the scale of 100,000 acres or more, with the primary constraints being surface waters that would stop the spread of fires. At KPRNA, the minimum unit to manage fire is considered to be the watershed, a natural ecosystem-level division.

Another unique characteristic of the tallgrass prairie is that a large fraction of the biomass and biological diversity of the system is below ground. This large, below-ground component, representing an extensive pool of stored carbon, nitrogen, and plant meristems, contributes to the great resiliency of the system to the effects of herbivory, fire, and drought. The prairie biota is sensitive to changes in natural disturbance regimes, yet recovers rapidly, under optimal conditions. Nonetheless, long-term burning, invasion by woody species, or continuous overgrazing may alter ecosystem function and composition of the below ground community.

The aquatic habitat found on native tallgrass prairie can be divided into three types: streams, wetlands, and groundwater. The streams can be further divided into permanent with intact oak gallery forest (e.g., Fox Creek) and intermittent grassland tributaries. The streams are characterized by highly variable flow throughout the year, with grassland tributaries dry at all but spring sites during some or much of the year (Gray and Dodds 1998). Wetlands are associated with spring or seep sites and stream riparian zones. About one-third of the plant diversity found on Konza Prairie is associated with such wet areas, even though they compose a relatively small proportion of the prairie (Freeman 1998). Groundwater habitats include karst-limestone aquifers in the uplands and unconsolidated sediments in the lowlands. Faunal biodiversity associated with streams, springs and groundwaters are moderate, but there is potential for endemic or rare species. Examples include groundwater invertebrates, and macroinvertebrates in springs. Endemic fish (e.g., Topeka Shiner, *Notropis topeka*) and mussels may be found in the larger streams. Ponds are not a natural part of tallgrass prairie ecosystems in the Flint Hills area. Flint Hills streams provide some of the few examples of lightly to moderately impacted streams draining prairie lands.

Given the above considerations, TAPR's potential biodiversity is high. The biodiversity and sustainable ecological integrity of this site can easily be enhanced through management alternatives (fire and grazing regimes), without the necessity for restoration and re-introduction of missing taxa or functional groups. The exceptions are the current lack of functional populations of the key large native herbivores (and their predators) on the site, and the lack of native bottomland tallgrass prairie that historically occupied the more mesic deep soils adjacent to the wooded riparian corridors.

Recent research results show positive relationships between native plant species richness and the long-term stability of plant community composition and production in tallgrass prairie (Hickman 1996). These results indicate that ecological factors and management practices that will enhance floristic and spatial diversity in Flint Hills tallgrass prairie also are predicted to enhance the quality and sustainability of the range resource for sustained animal production. Heterogeneity in the form of a dynamic vegetation mosaic also promotes vegetation-herbivore stability in Great Plains grasslands (Coughenour 1991).

It should be noted that the enhancement of native biodiversity and ecosystem function in tallgrass prairie does not imply simply the maximization of species richness. Rather, the focus is on incorporating the key processes mentioned above to increase the abundance of native species representing key functional groups and to reduce or eliminate exotic taxa.

Limitations of the Current Management Scenario

Intensive, Early Cattle Stocking

Based on current evidence, intensive early stocking of cattle reduces both heterogeneity and plant species diversity relative to season-long stocking. Continued use of this grazing system is predicted to gradually erode rather than enhance biodiversity (Hickman 1996; Collins and Steinauer 1998). Furthermore, there are no long-term data to indicate that early stocking results in sustained levels of plant productivity over extended time scales, i.e., several decades. Studies of vegetation responses to alternative grazing management approaches also indicate that animal stocking rates have a larger and often overriding influence on vegetation diversity and productivity compared to the effects of grazing systems (Hartnett et al. 1996).

Annual Burning

Annual burning reduces both heterogeneity and biodiversity (plants, birds, mammals, terrestrial invertebrates) relative to periodic burning at an average interval of 3 to 5 years (Gibson and Hulbert 1987; Collins and Wallace 1990; Knapp et al. 1998a). For example, it has been demonstrated that the practice of both annual burning and heavy grazing together diminishes bird populations, reducing both nesting success and productivity (Zimmerman 1997). Furthermore, current simulation models of tallgrass prairie also predict that chronic annual burning will result in gradual nutrient limitation and lower net plant productivity over long time scales, i.e., decades to centuries (Ojima et al. 1990, 1994; Seastedt et al. 1994).

Current Management Limitations

The current management scenario does not simulate the temporal variability characteristic of a native tallgrass prairie ecosystem. Although it incorporates certain elements (e.g., grazing pressure following post-fire regrowth), it results in all portions of the landscape receiving the same disturbance, at the same time of year, every year. This moves the system toward landscape homogeneity rather than heterogeneity, and it is very different from natural landscape dynamics, e.g., variation in seasonality of fire (Howe 1994). It lacks the spatial-temporal variability that creates a dynamic mosaic and that provides necessary refugia for populations differentially adapted to these natural disturbances.

Given the significant effects of native ungulates in enhancing various components of tallgrass prairie biodiversity and spatial heterogeneity, and their central role as the dominant herbivores in pre-settlement tallgrass prairie, their absence under current conditions is a correctable limitation to TAPR's potential biodiversity (Knapp et al. 1998a).

MANAGEMENT RECOMMENDATIONS

Baseline Inventory

An inventory of the distribution and abundance of all species should be given the highest priority. The information collected will form the baseline data for comparison of all future changes, and it will be used to evaluate if management is resulting in an increase in biodiversity. Therefore, it is critical to select the proper methodology, sample at a proper intensity, and exercise quality control over data collection.

Vegetation

A vegetation baseline inventory should include detailed initial sampling. Identical procedures should be used at yearly or multi-year intervals to monitor change. A technique to measure species frequency will be the most efficient method to characterize the vegetation (Bonham 1989). The technique used must measure plant basal frequency rather than frequency of foliar cover. Foliar cover varies throughout the year as the plants grow and with the influence of grazing. Foliar cover data collected from one week to the next will be different, and data collected from one day to the next may be different. Frequency of plant bases will vary little from one week to the next or even one month to the next, and grazing will not have an immediate effect.

Basal frequency data are collected at KPRNA and the Kansas State University range research areas using the modified step-point method (Owensby 1973; Hartnett et. al. 1996), and this method would be appropriate for TAPR. Using the same technique would better allow comparisons of vegetation responses at both sites.

Briefly, a site is subdivided by management unit (fire and grazing), range site, soil type, slope, or other definable characteristic. Transects are randomly established, and the modified step-point is positioned randomly along the transects. At each point, the plant closest to the point and the forb closest to the point are recorded. Generally, a minimum of 500 points is required per site, but the intensity of sampling will be determined by the amount of variation in the data. Therefore, preliminary data will have to be collected before sampling intensity can be determined.

Special attention should be given to any plant species listed in Kansas as being a species of concern because of rarity. Also, the locations of exotic species should be recorded, and their abundance should be quantified.

Finally, since a dynamic vegetation mosaic is a target, a baseline of remote imagery, ground-truthed for composition with classified communities and boundaries, should be completed so spatial patterns can be compared at several scales on a 5- to 10-year interval.

Aquatic

An aquatic baseline inventory should include detailed initial sampling followed by periodic follow-up sampling. Initial priorities should be to map the existing aquatic habitats and determine the distribution of organisms in these habitats. The mapping could include note of any areas with excessive rates of erosion. Routine water quality sampling of major springs, ponds, and streams will reveal if there are any gross pollution problems. Such assessment should occur in Fox Creek several times a year, and at least once initially on the small streams, ponds, and springs with standing water on the rest of the site.

It is suggested that all aquatic habitats be assessed with regard to unusual or rare invertebrates. Permanent streams should be thoroughly sampled for invertebrates and fish. Invertebrate sampling should be done with similar protocols to those used by Kansas Department of Health and Environment (1995) to allow comparison to their statewide data set. Endemic mussels are common in larger Kansas streams and rivers. Fox Creek and Palmer Creek should be sampled to determine what mussel species are present. The Topeka Shiner is likely to be listed as endangered and has been found at one location in the preserve. Detailed sampling should be done to determine the distribution of this fish in the preserve. There is a possibility that the endangered Neosho Madtom (*Noturus placidus*) will be found in Fox Creek and this should be determined as well.

Upland spring-fed pools may contain unique invertebrates and should be identified and sampled. The springs and existing wells within the preserve boundaries can also be used to assess the groundwater invertebrate communities; sieves placed on the outflows will catch groundwater organisms. It would be desirable to determine the species that are present in the groundwater and use the presence of these species as possible biological indicators of pristine conditions.

Insects

Species presence should be determined, at least that which can be discovered by qualitative sampling by sweep net, pit traps, or soil extraction. Presence data should be collected in each of the burning or grazing treatment areas, as well as in the historic ranch area and restored prairie and agricultural fields between the highway and Fox Creek. Indicator species (e.g., the regal fritillary butterfly) should be identified. Special attention should be paid to species in the Orthoptera, Lepidoptera, and Coleoptera (Arenza and Joern 1996).

Small Mammals

Species presence should be determined by live trapping along transects in each burning or grazing treatment area (or potential treatment area). Each transect should be composed of 20 stations placed 15 m apart. Each station should have two large Sherman live traps within 1 m of station. Trapping should occur over four consecutive days in the spring (March), summer (July), and autumn (October). Transects should be oriented so that they run from uplands to lowlands, across the limestone breaks.

Large Mammals

Since a browse line is becoming apparent along Fox Creek, some baseline estimate of white-tailed deer populations on the site is desirable. It may become necessary to subsequently control deer populations.

Birds

Relative abundance should be determined in June by conducting point counts (10 points per burning-grazing treatment) during a 10-minute counting period. Within a given treatment, points should be no closer than 250 m. All species and the number of individuals of each species observed (and/or heard) within the treatment area should be counted. Since there are few birds (except raptors) associated with upland prairie during the winter, similar sampling does not need to be conducted during the cold season. During the second and third weeks of April, all greater prairie-chicken leks should be located and the number of males present counted at least twice during the sampling period, with the maximum number observed recorded. Sampling should be completed within 2 hours of dawn, and the timing of the two visits to a lek should be randomly selected.

Amphibians and Reptiles

Species presence lists for these classes should be developed by qualitative sampling by appropriate methods (e.g., drift fences, drop cans, turning over rocks) in all habitats (Davis 1991).

Monitoring

Weather

A weather station should be established at TAPR at an early date. An automated station could efficiently collect data that would be invaluable in interpreting changes in biological communities in the future. Since summer rains are patchy, it would be advisable to place recording rain gauges at several sites.

Vegetation

Vegetation monitoring should be conducted each year for at least 5 years using the same methods as used in the baseline inventory. At that time, the data should be analyzed to determine how much it has changed from one year to the next. If changes in the vegetation are not dynamic, intervals between vegetation sampling could be increased.

Standing crop biomass should be determined at the end of each growing season using standard clipping procedures (Bonham 1989). These data will be helpful in determining utilization of the prairie species by grazing animals and in determining areas to be burned. Also remote imagery should be obtained every 5 years for analysis of the dynamics of plant communities over time and space.

Aquatic

Monitoring of invertebrate and fish communities only needs to be done every few years at major sites except where there are species of specific concern or following events that may have major impacts on aquatic biota. Methods used should be similar to those used to obtain the baseline data.

Insects

Common species (or indicator species) among the Orthoptera, Coleoptera, and Lepidoptera identified during baseline studies should continue to be censused using the most appropriate method (Arenza and Joern 1996).

Large Mammals

Abundance and distribution of deer should be followed, if baseline studies indicate present populations are close to the estimated carrying capacity. If and when bison (*Bison bison*), elk (*Cervus canadensis*), and/or pronghorn (*Antilocarpa americanus*) are restored to the area, census should be conducted on an annual basis.

Birds

Even though birds do not have a great impact on the grassland ecosystem, there is national concern for the documented decline in grassland species. Furthermore, the public is interested in birds. Therefore, it would be valuable to continue both the point counts and the prairie-chicken lek counts annually.

Other Taxa

Mechanisms must be in place so that checklists for mammals, reptiles, and amphibians can be continually updated even though these groups may not be regularly monitored.

Geographic Information System

A Geographic Information System (GIS) should be created for TAPR. Special attention should be placed on mapping and monitoring the prairie-forest ecotone. This ecotone should be remotely sensed and mapped at 5-year intervals. Areas of the prairie burned and not burned should be entered into the GIS each year. The anticipated patchy burns will be difficult to monitor using other methods.

Upland Habitats

Research conducted at several sites in the region indicates that the best-functioning natural prairie ecosystem results from a heterogeneous mixture of disturbances from fire and grazing over large landscape areas (Knapp et al. 1998b). With these mixed disturbances as a goal, the best management strategy would include large semi-free ranging herds of native grazing ungulates (bison, pronghorn, and elk) at historic stocking rates. An area of at least 100,000 acres is most effective for maintaining a large free ranging herd. While large carnivores (wolves and grizzly bear) were also important in the tallgrass prairie ecosystem, the introduction of large carnivores would not be practical in an area this small.

Simultaneously, fire is absolutely essential to the maintenance of native tallgrass prairie on the same large scale (Knapp et al. 1998a). Large fires increase biodiversity and ecosystem function by effectively controlling woody growth, encouraging a diverse mixture of desirable prairie species, enhancing nutrient cycling, and promoting other ecosystem benefits (Collins and Wallace 1990). Historically, the long-term fire return interval averaged between 3 and 5 years, with random variation about its mean being critical. This variation in temporal and spatial responses creates a dynamic mosaic of grassland conditions that ensure long-term sustainability of tallgrass prairie structure and function, fully resistant to external management practices. In addition, fire occurred at any time of the year, with greater frequency in the fall and spring (Howe 1994). These conditions also would benefit the biodiversity of the consumer organisms. Ideally, management should reflect historical patterns. In this regard, fires will be most effective in areas with greater fire fuel loads that reflect local patchy grazing effects and soils.

Tallgrass Prairie National Preserve does not cover 100,000 acres. However, the actual area of TAPR is sufficient to employ the same disturbance regimes of fire and grazing in a scaled-down version to similarly enhance the biodiversity by creating appropriately sized mosaics of prairie conditions. Prescribed burning at historically encountered levels should be employed in all tallgrass prairie habitats in the TAPR management plan. Burn schedules should take at least three factors into consideration: (a) minimum fuel load, (b) a long-term mean fire return interval of 3 years with random scheduling about this mean value, and (c) shifting burning sites among years in response to relative fuel conditions.

Grazing by bison and other large native herbivores is essential as the grazing tactic of choice for a major portion of the preserve (minimum of 7,000 acres) to increase biodiversity. Such large areas are needed to maintain normal herd social structure and behavior, including foraging routes. Diet selection and dynamics of a properly managed bison herd will be the most viable grazing management to enhance biodiversity at TAPR. Fences constructed for the large herbivores should be built to standards that will contain elk and antelope. This would make the future introduction of these species possible without additional construction.

Traditional season-long and cow-calf cattle ranching practices could be reinstated on the remaining portions of the preserve. While less effective than bison for enhancing biodiversity, this arrangement best facilitates interpretation of ranching activities. At moderate stocking rates, grazing by cattle does enhance biodiversity (Collins and Barber 1985) compared to no grazing. In addition, it provides opportunities to compare grazing effects of historical cattle grazing practices with those of bison on tallgrass prairie biodiversity.

The current management practice of double stocking with yearling cattle should be replaced with season-long (May 1 to October 15) grazing of yearling cattle and a year-round cow/calf operation. This recommendation better reflects historical practices on the ranch and also increases biodiversity more than the current double stocking system. Prescribed burning should follow the same schedule described above with an average (but variable) fire return interval of 3 years using the same criteria for determining exactly where burns should occur in particular years.

Finally, a small portion of TAPR should be set aside to illustrate the effects of prescribed burning at an average interval of 3 years with no grazing. This treatment option will be particularly important as a control for interpreting the impact of the combined fire and grazing treatments for enhancing tallgrass prairie biodiversity. Relatively small demonstration areas could be devoted to grazing with no fire and an area with neither fire or grazing. No need is seen, even for interpretive reasons, for replicating the current practice of double early stocking with annual burns given the anticipated significant and long-term negative impact on biodiversity associated with this contemporary management practice.

Riparian and Aquatic Habitats

Floodplain Tallgrass Prairie Restoration

According to the Kansas Natural Heritage Inventory, high-quality floodplain tallgrass prairies and riparian areas are rare plant communities in Kansas. TAPR's floodplain prairie (adjacent to the riparian zone) has been converted to non-native grasses (primarily smooth bromegrass, *Bromus inermis*) along Fox Creek or has been subjected to high impact of cattle. It should be restored to native tallgrass prairie and cross timbers over as much of this area as possible. It is recognized that some of this area may be used for agricultural interpretation, which may include the production of historic crops and feed crops for livestock. The restored prairie plant community could also be of benefit to the historic interpretation of the ranch as part of the area (perhaps one-third per year) could be harvested as prairie hay as needed to feed livestock.

Restoration of the area should be focused on reestablishment of as many plant species as possible and by using local and regional native seed sources following examples at Walnut Creek National Wildlife Refuge with other restoration efforts. In addition, consideration should be given to transplanting available plants and soil, especially if there is a source due to highway construction or other local development. It may require a large number of volunteer hours to accomplish this restoration effort, given the need to collect local seed and for weedy species removal during establishment of the prairie.

Riparian Area

Cattle have significantly degraded the riparian area by fostering a poorly developed understory with little grass cover, which would provide fuel for a prescribed fire, and potentially increased bank erosion. The impacted riparian area should have the smooth bromegrass (*Bromus inermis*) removed, and native grasses should be planted up to the edge and underneath the canopy of the riparian area and encouraged by management practice (prescribed burning) to move underneath the tree overstory. Fire should be reestablished here to encourage natural processes. Burning more than once every 5 years may be too frequent and might not allow for recruitment of woody species. In addition, any of the riparian areas to be used for watering of domestic livestock (even in areas to the east that are not floodplain) should be fenced and alternative water sources (such as piping or windmills) should be considered. A change to bison as the major large ungulate should result in less impact and enhance the recovery process. A long-term concern may be overpopulation by deer; and this possibility should be assessed approximately every 5 years.

Springs and Seeps

Springs and seeps are recognized as "hot spots" of biodiversity on the prairie landscape. This is true for vegetation that is associated with the margins of the springs and for the aquatic invertebrates that may be found in the spring-fed pools. For example, about 28 percent of the 311 vascular plant species found at Konza Prairie have been assigned wetland indicator status in the Central Plains region (Knapp et al. 1998a). In another example, the only endemic species (terrestrial or aquatic) found thus far on nearby KPRNA is a mayfly that inhabits one upland spring-fed reach of a spring (Charlton and Fritz, personal communication). Given that livestock may have a major impact on these systems, we recommend that consideration be given to fencing springs and seeps, in areas grazed by cattle, that are found to harbor rare species.

Some of the springs have been modified by addition of spring boxes from which pipes flow to stock watering tanks. This is likely the traditional method for ensuring stock had access to water in the prairie uplands, and these should be left in place. However, given the importance of the springs and seeps for biodiversity, additional spring sites should not be developed for livestock watering.

Ponds

Ponds are not a natural part of the prairie landscape except as very small spring pools and as oxbow ponds near rivers. The current ponds serve as sources of water for livestock, but also encourage livestock to have a greater influence on water quality within the watershed and downstream. These ponds were relatively rare in livestock operations before earth-moving machines were readily available.

No new ponds should be constructed. Consideration should be given to allowing ponds to fill with sediment and not replacing them, unless they are the only option for livestock watering. Wells may be used to provide water for livestock in upland regions as the need arises. The option of breaching existing ponds may be considered, but care should be used if this is attempted to avoid large releases of sediment and non-native fish downstream that would have adverse effects on stream biota.

Other Management Issues

Infrastructure Development

In keeping with the goal of enhancing the tallgrass prairie ecosystem, infrastructure development in all areas of native prairie should be kept to a minimum. Specifically, new buildings, roads, farm ponds, gas and oil infrastructure, and other development would not be compatible with this goal. This is particularly important given that the desired management scenarios proposed here are already limited by the size of the preserve.

Surrounding Development

Surrounding development could greatly impact the ability of the NPS to increase TAPR's biodiversity. Adjacent buildings and residential development could adversely affect biodiversity by restricting animal movements, interrupting corridors, providing exotic predators (cats and dogs), and limiting the use of fire due to safety concerns. A further concern is the influence of surrounding vegetation. It may not be possible to manage the increased seed source of undesirable species originating from the adjacent properties. The preserve is not an island. Although fences restrict the movement of large ungulates, significant movements of most species (including all birds, small mammals, plants, etc.) to and from adjacent lands will occur. For these reasons, surrounding development must be considered from a biological perspective and should be discouraged. Management of the surrounding land as native tallgrass prairie range should be encouraged.

Furthermore, entities other than the NPS, including local government and nonprofit organizations are encouraged to seek conservation easements on lands adjacent and near TAPR to limit development. Conservation easements allow for private landowners to donate or sell their development rights, while still using their lands for agricultural and ranching purposes. The American Farm and Ranch Protection Act (enacted August 5, 1997) allows for significant tax benefits for landowners who enter into conservation easement agreements near NPS land.

Exotic Species

Non-native species are known to be a problem in national parks (Hiebert and Stubbendieck 1993) and the prevention of new exotic species should be a goal of management. Monitoring to identify noxious and known exotic species should be conducted. Special attention should be given to state-listed noxious weeds, like musk thistle (*Carduus nutans*) and field bindweed (*Convolulus arvense*), and especially to potentially problematic species such as *Sericea lespedeza* (*Lespedeza cuneata*) and Caucasian bluestem (*Andropogon bladhii*), which should be controlled and eradicated if possible before they have the opportunity to become fully established. Control measures should be considered for any non-native species that becomes problematic. Across the preserve, there should be general avoidance of activities that encourage annual, weedy species. If horses are allowed on the preserve, or if supplemental cattle or other feed is provided, weed-free hay (with no smooth bromegrass, tall fescue, Kentucky bluegrass, or clover seed) should be required. In addition, the introduction of aquatic game fish species should be discouraged.

Encroachment by Trees

Historical data, such as the U.S. Government Land Surveys, indicates that in pre-settlement times trees were restricted to the major stream courses in the area and were probably not found in upland areas (Freeman 1998). The treeless vistas were a product of fire, grazing, and the absence of tree seeds. Given the goal of enhancing the tallgrass prairie ecosystem, encroachment by trees into prairie habitats should be prevented through management activities. A monitoring program that assesses woody vegetation every 10 years should indicate any potential problems. Although fire and grazing will greatly discourage tree establishment, mechanical tree removal may be warranted in areas that do not burn well or often enough. It should be noted that several woody shrubs, including New Jersey tea and rough-leaved dogwood, are considered desirable in limited abundance and will be important food sources for elk and habitat for birds.

Erosion

Erosion will have negative impacts on both water quality and prairie quality. Several factors may lead to erosion in excess of natural rates. Removal of vegetation on steep slopes, be it by road construction, excessive grazing, or by other development (e.g., gas well installation and operation, new building construction) could lead to increased rates of erosion. Removal of gravel from stream channels (discussed immediately below) and disturbance of vegetation by driving off roads may also increase erosion rates. Measures should be taken to minimize erosion. In areas where excessive erosion has occurred and been remedied, native vegetation should be reestablished.

Gravel Removal from Stream Channels

Removal of gravel from stream channels will have several adverse effects, and therefore gravel removal should be prohibited. There is an immediate negative impact on aquatic biota and less-direct negative impacts of increased sediments. Sediment accumulation alters the invertebrate communities of tallgrass prairie streams (Fritz 1997). This increased sedimentation would occur even in streams that were dry when the gravel was removed; the sediment load would be high when flow resumes.

An additional negative impact of gravel removal from channels is an increased rate of erosion. The process of gravel removal will damage the banks leading to increased erosion. In addition, the down-cutting of stream channels leads to increased water velocity upstream, increasing bed load and upstream erosion.

Fishing and Hunting

Managing the ponds for fishing generally includes the introduction of non-native species, or species not commonly found in small prairie streams. Because these fish will move downstream during flooding events, we recommend against the stocking of farm ponds.

Hunting should not be excluded as a management tool. For example, it may be desirable to reduce densities of some species if their impact on biodiversity is excessive. An example of this would be high populations of deer and associated browsing impacts on the woody vegetation in riparian areas. Given the lack of natural predators, hunting may represent the best methods of control. Hunting is consistent with Native American and early Euroamerican use of the land.

Summary and Conclusions

Summary of Findings and Recommendations

The natural prairie is a dynamic mosaic of successional stages resulting from the interaction of climate, fire, and grazing. A tallgrass prairie ecosystem is resilient, and native species are well-adapted to the pervasive influences of natural disturbances such as fire, grazing, and drought. Most of the biomass in tallgrass prairie is found below the surface. This provides for resistance to drought, rapid regrowth following the defoliation by fire, and rapid response to increased moisture and nutrients. Thus, the panel believes that the potential to enhance biodiversity at TAPR is high.

Most components of the system are believed to be present except for large ungulates (bison, elk, and pronghorn) and large predators (wolf, grizzly bears, and mountain lion). The panel further sees the most important action to promote biodiversity is to create a mosaic of disturbance regimes (fire and grazing). The predicted response is a mixture of guilds of species (warm-and-cool season grasses, spring and fall flowering forbs, legumes, and shrubs).

As most animal species are dependent on the vegetation, management actions to increase plant diversity at the landscape scale will result in a more diverse animal community. Heterogeneous fire and grazing regimes are the key. Management for enhancement of tallgrass prairie and productive range are compatible goals. The panel recommends that the NPS concentrate on management for biodiversity. Pursuit of these goals most likely will not maximize rangeland productivity in the short term, but it will result in a sustainable high-quality range that exhibits high biodiversity at the landscape scale.

The present management scheme of annual spring fire (and clean burns) and double stocking from May to July has the effect of homogenizing the landscape. Double stocking is predicted to result in a deterioration of range and biodiversity within several decades.

It is unlikely that rare or endemic terrestrial plant or animal species will be discovered at TAPR. However, springs, seeps, and streams are "hot spots" for diversity.

Based upon the above and information from research conducted at in other tallgrass prairies sites and at KPRNA in particular, the workshop participants make nine recommendations.

(1) Gathering of baseline information on the biological and related physical resources of TAPR should be of highest priority. Monitoring schemes should be developed to detect trends over time and space and to evaluate the effectiveness of management schemes implemented.

(2) Create a heterogeneous dynamic landscape by establishing burn units that are burned at different times with an average (but variable) fire return interval of 3 years, by restoring bison to the majority of TAPR, and by reducing stocking rates and switching to season-long grazing by cattle in the remainder.

(3) Restore the majority of the floodplain to native prairie, as this is one of the rarest community types in the Flint Hills.

(4) No new ponds should be built nor should recreational fishing be promoted. Ponds are unnatural to the system and have impacted secondary streams throughout the preserve. Recreational fishing normally involves the introduction of non-native fish that then enter and impact creeks downstream.

(5) Minimize development within and adjacent to the park. The size of the preserve is minimal for restoration of bison and fire management at a landscape scale. Developments adjacent to the preserve could impact fire management, create sources of feral animals and invasive plants, and obstruct the vista.

(6) Gravel mining of streams should not occur. Impacts include erosion, disturbance of aquatic habitat, and increased siltation.

(7) As springs are "hot spots" of diversity, NPS management should consider protection from livestock for those areas found to be species rich or to contain rare species.

(8) Hunting should remain an option as the natural predators have been extirpated. Overpopulation of white-tailed deer is a specific concern.

(9) Exotic plants should be monitored and controlled. Special attention should be placed on the state list of noxious weeds (e.g., musk thistle and bind weed) and taxa known to be a problem in the area (*Sericea lespedeza* and caucasion bluestem).

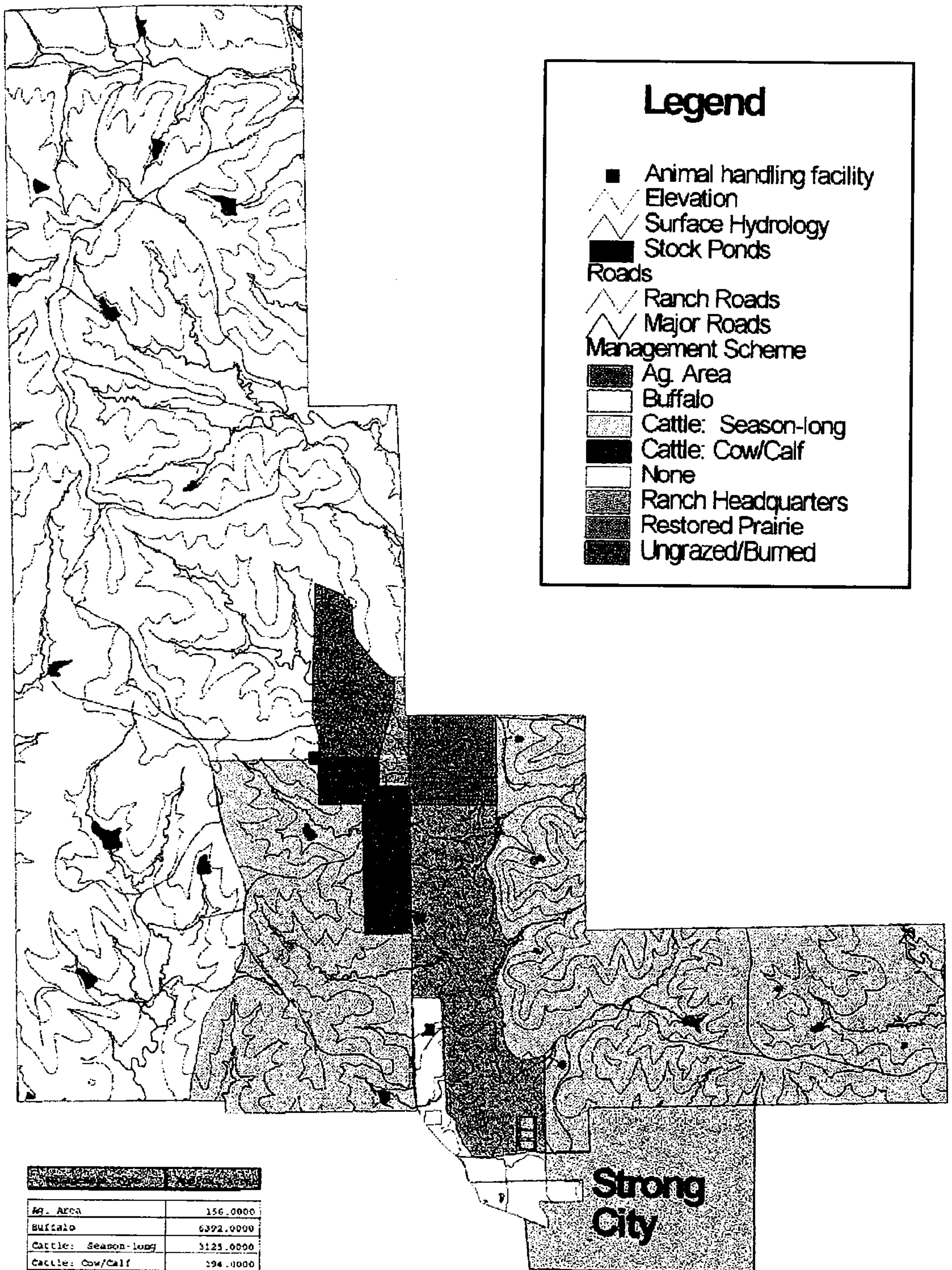
Model Management Scheme

The Model

A conceptual spatial management model was developed to illustrate recommendations and to serve as a starting point for development of a holistic management scheme for TAPR (Figure 3).

The consensus of the group is that it is essential to switch grazing from cattle to bison for a major portion of the preserve. The group recommends that the northern three grazing units and the western portions of the two southwestern grazing units be fenced for bison and the possible reintroduction of elk and pronghorn. Old barbed-wire fences should be removed and the historic rock fences (an important cultural resource addressed in the legislation) left in place. This unit should be divided into 5 or 6 burn units and a scheme developed to burn each at different years and various times of the year seeking an average but variable fire return interval of 3 years. The practice of "clean burns" should be discontinued and fire should be allowed to create a natural mosaic. Inventory and monitoring should be stratified according to grazing and burn units. Gas wells should be protected in a non-destructive and non-obtrusive manner. Bison spend much less time than cattle in riparian zones and streams and thus do not need to be restricted from streams. However, some initial restoration may be required in riparian areas presently impacted by cattle. New bison management schemes do not need to be created as they have been developed by The Nature Conservancy for the Tallgrass Prairie Preserve in Oklahoma and the Niobrara Preserve in Nebraska.

The group recognizes the need to have some of the area grazed by cattle to interpret the historic ranching scene. The model calls for a season-long (May 1 to October 15) grazing regime by cattle at conservative stocking rates (about 90 percent of normal) for the eastern portions of the two southwest grazing units and the grazing units east of Fox Creek. As for the bison grazing units, multiple burn units should be created



[illegible]	[illegible]
Ag. Area	156.0000
Buffalo	6392.0000
Cattle: Season-long	3125.0000
Cattle: Cow/Calf	394.0000
None	199.0000
Ranch Headquarters	49.0000
Restored Prairie	582.0000
Ungrazed/Burned	202.0000

Management strategy proposed by TAPR biodiversity panel, 1997.

Figure 3. Spatial model for the management of Tallgrass Prairie National Preserve.

within each grazing unit. Fences will need to be constructed to exclude cattle from the Fox Creek riparian area.

To reduce costs and minimize developments within TAPR, one handling facility should be constructed at the boundary between bison and cattle grazing units. The new state-of-the-art handling facility at Konza Prairie serves as a model.

As some visitors to TAPR will anticipate seeing cattle and cowboys all times of the year, a small cow-calf operation could be developed in the grazing unit adjacent to the ranch headquarters. Efforts should be made to introduce livestock varieties true to the historic context.

The model also provides for demonstration and interpretation areas around the ranch headquarters to allow visitors to see tall grass and to demonstrate the effects of fire without grazing. A display of the underground portion of the prairie is also recommended. Public access should be provided to a portion of Fox Creek as prairie streams are a significant part of the tallgrass prairie ecosystem.

The model calls for the restoration of the majority of the cultivated and brome fields in the floodplain of Fox Creek as this is one of the rarest vegetation types of the Flint Hills. Seeds and propagules should be collected from the local area. Efforts should be made to plant as many native species as possible to increase the diversity of the preserve. Fire should also be used to maintain the riparian zones but the fire return interval should be 5 years or more to allow development of woody vegetation. The floodplain directly across from the ranch headquarters could continue to be used for agriculture for interpretation and support of the cow-calf operation.

Based upon baseline inventories, those seeps and springs shown to provide habitat for a high diversity of species and/or rare and endangered species should be fenced.

Intermediate Steps

The panel realizes that it will not be possible to implement all of the actions called for in the above conceptual model immediately. However, intermediate actions can be taken to restore and increase the biodiversity of TAPR. Figure 4 provides guidance on the relative contributions of various manipulations of grazing and fire elements. Recommended intermediate actions include:

(1) Complete baseline inventories of all major groups of organisms as soon as possible. Stratify sampling to fit the most probable future grazing and burn units.

(2) Switch grazing regime from early season double stocking to a season-long grazing regime with conservative stocking rates.

(3) Discontinue annual "clean burns." Develop multiple burn units and switch to an asynchronous scheme (years and season) with an average but variable fire return interval of 3 years.

(4) Initiate restoration of riparian areas where needed (may have to be fenced to allow establishment of native vegetation).

(5) Initiate restoration of portions of the floodplain along Fox Creek.

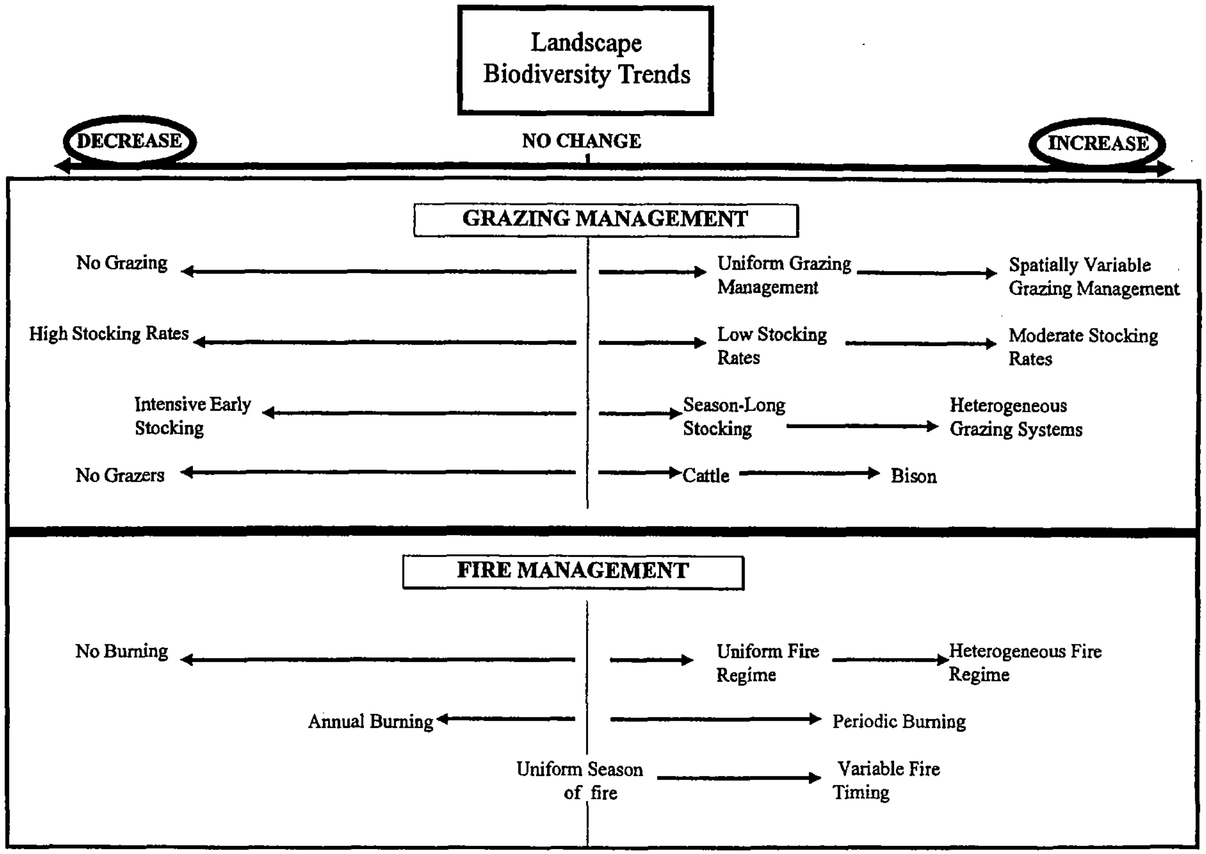


Figure 4. Relative contributions of various grazing and fire management regimes to landscape scale biodiversity in tallgrass prairie ecosystems.

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APPENDIX

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Education

Ph.D. 1983 University of Illinois, Plant Biology.
M.S. 1978 Bucknell University, Ecology.
B.S. 1977 Bucknell University, *summa cum laude*, Biology.

Professional Experience and Employment

1996- Professor of Biology, Kansas State University.
1995- Director, Konza Prairie Research Natural Area.
1991-1995 Associate Professor of Biology, Kansas State University.
1986-1990 Assistant Professor of Biology, Kansas State University.
1983-1986 Assistant Professor of Biology, University of South Florida.
1977-1983 Teaching and Research Assistant, University of Illinois.
1981-1982 Lecturer in Botany, University of Illinois.
1977 Research Assistant, Archbold Biological Station, Lake Placid, Florida.

Research Interests

Ecology of Mycorrhizae, Grassland Plant Population Biology, Plant-Herbivore Interactions, Ecology of Tallgrass Prairie, Fire Ecology.

Professional Memberships

Ecological Society of America, Society for Range Management, Botanical Society of America, Society for Conservation Biology.

Elected Membership: International Society of Plant Population Biologists, British Ecological Society, Phi Beta Kappa, Phi Eta Sigma, Phi Sigma, Sigma Xi.

Selected Publications (last five years) from a Total of 45 (1979-1996)

Vinton, M.A. and D.C. Hartnett. 1992. Effects of bison grazing on *Andropogon gerardii* and *Panicum virgatum* in burned and unburned tallgrass prairie. *Oecologia* 90:374-382.

Vinton, M.A., D.C. Hartnett, E.J. Finck and J.M. Briggs. 1993. Interactive effects of fire, bison (*Bison bison*) grazing and plant community composition in tallgrass prairie. *Amer. Midl. Nat.* 129:10-18.

Fay, P.A., D.C. Hartnett, and A.K. Knapp. 1993. Increased photosynthesis and water potentials in *Silphium integrifolium* galled by cynipid wasps. *Oecologia* 93:114-120.

Hartnett, D.C. 1993. Regulation of clonal growth and dynamics of *Panicum virgatum* in tallgrass prairie: effects of neighbor removal and nutrient addition. *Amer. J. Bot.* 80:1114-1120.

Hartnett, D.C., B.A.D. Hetrick, G.T. Wilson and D.J. Gibson. 1993. Mycorrhizal influence on intra- and interspecific neighbour interactions among co-occurring prairie grasses. *J. Ecol.* 81:787-795.

Hetrick, B.A.D., D.C. Hartnett, G.W.T. Wilson and D.J. Gibson. 1994. Effects of mycorrhizae, phosphorus availability and plant density on yield relationships among competing tallgrass prairie grasses. *Can. J. Bot.* 72:168-176.

Hartnett, D.C., R.J. Samenus, L.E. Fischer and B.A.D. Hetrick. 1994. Plant demographic responses to mycorrhizal symbiosis in tallgrass prairie. *Oecologia* 99:21-26.

Hartnett, D.C. and K.H. Keeler. 1995. Population Processes In *The Changing Prairie*. A. Joern and K.H. Keeler (eds.), pp. 82-99. Oxford University Press, Oxford.

Pfeiffer, K.E. and D.C. Hartnett. 1995. Bison selectivity and grazing responses of little bluestem in tallgrass prairie. *J. Range Manage.* 48:26-31.

Hartnett, D.C. (editor). 1995. *Prairie Biodiversity. Proceedings of the Fourteenth North American Prairie Conference, Manhattan, Kansas.* 257 pp.

Hartnett, D.C. 1995. Role of grazing and fire management in grassland diversity and production. pp. 72-76 In: *Fifty Years of Range Research.* Kansas State University.

Hickman, K.R., D.C. Hartnett, and R.C. Cochran. 1996. Effects of grazing systems and stocking rates on plant species diversity in Kansas tallgrass prairie. In *Rangelands in a Sustainable Biosphere: Proc. Fifth International Rangeland Congress,* N.E. West (ed.), pp. 228-229.

Hartnett, D.C., K.R. Hickman and L.E. Fischer Walter. 1996. Effects of bison on plant species diversity in tallgrass prairie. In *Rangelands in a Sustainable Biosphere: Proc. Fifth International Rangeland Congress,* N.E. West (ed.), pp. 215-216.

Fischer Walter, L.E., D.C. Hartnett, B.A.D. Hetrick and A.P. Schwab. 1996. Interspecific nutrient transfer in a tallgrass prairie plant community. *Amer. J. Botany* 83:180-184.

Fay, P.A., D.C. Hartnett, and A.K. Knapp. 1996. Plant tolerance of gall-insect attack and gall insect performance. *Ecology* 77:521-534.

Hartnett, D.C., K.R. Hickman and L.E. Fischer Walter. 1996. Effects of bison grazing, fire, and topography on floristic composition and diversity in tallgrass prairie. *J. Range Manage.* 49: 413-420.

Hartnett, D.C., A.A. Steuter and K.R. Hickman. 1997. Comparative ecology of native versus introduced ungulates. In *Ecology and Conservation of Great Plains Vertebrates,* F. Knopf and F. Samson (eds.), pp. 72-101. Springer-Verlag.

Wilson, G.T.W., and D.C. Hartnett. 1997. Effects of mycorrhizae on plant productivity and species abundances in tallgrass prairie microcosms. *Amer. J. Bot.* 84:478-482.

Hartnett, D.C., and P.A. Fay. 1998. Plant populations: patterns and processes. In *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie.* A.K. Knapp, J.M. Briggs, D.C. Hartnett and S.L. Collins (eds.), Chapter 6. Oxford University Press.

Collins, S.L., J.M. Briggs, D.C. Hartnett, and A.K. Knapp. 1998. The dynamic tallgrass prairie: Synthesis and research opportunities. Chapt. 17 In:. *Grassland Dynamics: Long-term Ecological Research in Tallgrass Prairie,* A.K. Knapp, J.M. Briggs, D.C. Hartnett and S.L. Collins (eds.), Chapter 17. Oxford University Press.

Knapp, A.K., J.M. Briggs, D.C. Hartnett, and S.L. Collins (editors). 1998. *Grassland Dynamics: Long-Term Ecological Research in Tallgrass Prairie*. Oxford University Press.

Damhoureyeh, S.A., and D.C. Hartnett. 1997. Effects of bison and cattle on growth, reproduction, and abundances of five tallgrass prairie forbs. *Amer. J. Bot.* (in press).

Hickman, K.R., D.C. Hartnett, R.C. Cochran, and C.E. Owensby. 199 . Effects of grazing systems and stocking densities on the structure, composition, and biodiversity of tallgrass prairie plant communities. *J. Range Manage.* (submitted).

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Education

Ph.D.	1977	University of Texas at Austin, Zoology; Population Biology; Insect Ecology.
B.S.	1970	University of Wisconsin, Zoology.

Professional Experience

1990-	Professor, School of Biological Sciences, University of Nebraska, Lincoln.
1986-1991	Director, Cedar Point Biological Station.
1983-	Courtesy Appointment, Department of Entomology, University of Nebraska, Lincoln.
1982-1990	Associate Professor, School of Biological Sciences, University of Nebraska, Lincoln.
1978-1982	Assistant Professor, School of Life Sciences, University of Nebraska, Lincoln.
1977-1978	Postdoctoral Research. School of Life Sciences, University of Nebraska, Lincoln.
1971-1977	Graduate Student, University of Texas at Austin.

Research Interests

Insect ecology/population and community ecology, plant/animal interactions and chemical ecology, populations dynamics and behavior, grassland ecology. Primary interests: *insect populations and community ecology* (ecological and evolutionary mechanisms responsible for directing observed patterns of species coexistence and resource use), *insect/plant interactions* (mechanisms promoting and deterring feeding by insects and the ecological and evolutionary responses by plants), and *grassland ecology* (mechanisms responsible for maintaining species diversity in grasslands).

Honors and Professional Recognition

Board of Examiners, Graduate Record Exam, Biology Advanced Test (1992-present).
Quinney Visiting Scholar, Utah State University (1993).
Nebraska University Foundation Parents Teaching Award (1993).
Nebraska University Students Teaching Recognition (1996).
Associate Editor of Invertebrate Zoology, American Midland naturalist (1991-1995).
United States Department of Agriculture National Research Initiative Competitive Grants Panel, Entomology (1996).
NSF Ecology Grants Panel (1997-present).
Board of Editors, *Ecology & Ecological Monographs* (1997-present).

Recent Relevant Publications

Joern, A. and S.T. Behmer. 1998. Impact of diet quality on demographic attributes in adult grasshoppers (Acrididae) and the nitrogen limitation hypothesis. *Ecological Entomology* (in press).

Joern, A. and S.T. Behmer. 1997. Importance of dietary nitrogen and carbohydrates to survival, growth, and reproduction in adult *Ageneotettix deorum* (Orthoptera:Acrididae). *Oecologia* (in press).

Arenz, C.L. and A. Joern. 1996 Prairie legacies—invertebrates. Pp. 91-109 In *Prairie Conservation:Preserving North America's Most Endangered Ecosystem,* F.B. Samson and F.L. Knopf, eds. Island Press, Covello, California.

Belovsky, G.E. and A. Joern. 1995. The dominance of different regulating mechanisms for rangeland grasshoppers. In *Population Dynamics: New Approaches and Synthesis,* N. Cappuccino and P.W. Price (eds) pp. 359-386. Academic Press, San Diego.

Joern, A. and K.H. Keeler (eds). 1995. *The Changing Prairie: North American Grasslands*. Oxford University Press. New York.

Behmer, S.T. and A. Joern. 1994. The influence of proline on diet selection: sex-specified feeding preferences by the grasshoppers *Ageneotettix deorum* and *Phoetaliotes nebrascensis* (Orthoptera:Acrididae). *Oecologia* 98:76-82.

Yang, Y. 1994. Gut size changes in response to variable food quality and body size in grasshoppers. *Functional Ecology* 8:36-45.

Yang, Y. and A. Joern. 1994. Compensatory feeding in response to variable food quality by *Melanoplus differentialis*. *Physiological Entomology* 19:75-82.

Yang, Y. and A. Joern. 1994. Influence of diet, developmental stage and temperature on food residence time. *Physiological Zoology* 67:598-616.

Alward, R.D. and A. Joern. 1993. Plasticity in grass responses to herbivory. *Oecologia* 95:358-364.

Mole, S. and A. Joern. 1993. The foliar phenolics of Nebraska sandhills prairie graminoids: between years, seasonal and interspecific variation. *Journal Chemical Ecology* 19:1861-1874.

Behmer, S.T. and A. Joern. 1993. Dietary selection by the generalist grasshopper, *Phoetaliotes nebrascensis* (Orthoptera: Acrididae) based on the need for phenylalanine. *Functional Ecology* 7:522-527.

Joern, A. 1992. Variable impact of avian predation on grasshopper assemblies. *Oikos* 64:458-463.

Joern, A. and S.B. Gaines. 1990. Population dynamics and regulation in grasshoppers. In *Biology of Grasshoppers*. R.F. Chapman and A. Joern (eds.) pp. 415-482. John Wiley and Sons. New York.

Chapman, R.F. and A. Joern (eds.). 1990. *Biology of Grasshoppers*. John Wiley and Sons. New York.

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Education

Ph.D. 1991 University of Kansas, Lawrence, Systematics and Ecology.

Professional Experience and Employment

1996 -- Environmental Studies Program, University of Kansas Courtesy Assistant Professor (0.25 FTE).

1992 Kansas Biological Survey, University of Kansas, Assistant Scientist (0.75 FTE).

Courtesy Faculty for the Departments of Botany, and Systematics and Ecology, University of Kansas, for graduate student supervision and teaching.

Publications

Kindscher, K. and L. Tieszen. (in press). Floristic and Soil Organic Matter Changes after Five and Thirty-five Years of Native Tallgrass Prairie Restoration. *Restoration Ecology*.

Kindscher, K. and N. Scott. 1996. Land Ownership and Tenure of the Largest Land Parcels in the Flint Hills of Kansas. *Natural Areas Journal.*

Kindscher, K. and P.V. Wells. 1995. Prairie Plant Guilds: an Ordination of Prairie Plant Species Based on Ecological and Morphological Traits. *Vegetation* 117: 29-50.

Kindscher, K. 1992. *Medicinal Wild Plants of the Prairie--an Ethnobotanical Guide*. Lawrence: University Press of Kansas; contains 203 native prairie species, illustrated with line drawings and maps.

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Education

Ph.D. 1974 Rangeland Ecology and Management, Texas A&M University.
M.S. 1968 Agronomy (Range Management), University of Nebraska.
B.S. 1966 Agronomy (Conservation), University of Nebraska.

Professional. Experience and Employment

1997 - Director, Center for Great Plains Studies (0.5 FTE).
1982 - Professor of Agronomy (Rangeland Ecology), University of Nebraska (0.5 FTE).
1991 - Research Assoc., Division of Botany, University of Nebraska State Museum (courtesy).
1992 - Professor, Chadron State College (adjunct).

Research Interests

The ecology of rangeland plant communities, influences of prescribed burning on native vegetation and target woody species, long-term historical vegetation dynamics, and ecology and propagation of the endangered *Penstemon haydenii.*

Professional Memberships and Honors

Society for Range Management.
Society for Ecological Restoration.
Prairie/Plains Resource Institute.
American Penstemon Society.
National Association of Colleges and Teachers of Agriculture.
Natural Science Society.
Natural Areas Association.
Nebraska Academy of Sciences.
Alpha Zeta, Gamma Sigma Delta, Phi Sigma.
Speakers Bureau, University of Nebraska, 1997–1998.
Recognition Award for Books Published, University of Nebraska Chancellor's Office, 1995.
Recognition Award for Contributions to Students, University of Nebraska Parents Association Teaching Council, 1991, 1992, 1993, 1994, and 1996.
Distinguished Teaching Recognition, College of Agricultural Sciences and Natural Resources, 1994.
Fellow Award, Society for Range Management, 1991.
President's Citation, Society for Range Management, 1989.
Conservation Award, Nebraska Statewide Arboretum, 1987.
Outstanding Undergraduate Teaching Award, Range Science Ed. Council, Soc. for Range Mgmt, 1987.
Honor Award, Nebraska Statewide Arboretum, 1986.
Range Management Service Award, Society for Range Management, Nebraska Section, 1986.
Outstanding Service Award, Range Management Club, 1981.

Selected Publications (1993-present)

Books of a total of 9

Stubbendieck, James, Stephan L. Hatch, and Charles H. Butterfield. 1997. *North American Range Plants*. 5th Edition. University of Nebraska Press, Lincoln, 501 pages.

Stubbendieck, James, Geir Y. Friisoe, and Margaret R. Bolick. 1995. *Weeds of Nebraska and the Great Plains*. 2nd Edition. Nebraska Department of Agriculture, Lincoln, 621 pages.

Stubbendieck, James, Geir Y. Friisoe, and Margaret R. Bolick. 1994. *Weeds of Nebraska and the Great Plains*. Nebraska Department of Agriculture, Lincoln, 589 pages.

Stubbendieck, James, Stephan L. Hatch, and Charles H. Butterfield. 1993. *North American Range Plants*. 4th Edition. University of Nebraska Press, Lincoln, 493 pages.

Journal Articles of a total of 107

Ortmann, John, James Stubbendieck, Robert A. Masters, George H. Pfeiffer, and Thomas B. Bragg. 1998. Efficacy and cost of controlling eastern redcedar. *Journal of Range Management* 51: (in press). (Journal series 11707).

Miles, Katherine L., James Stubbendieck, Charles H. Butterfield, Walter H. Schacht, and Robert A. Masters. 1998. Smooth sumac control with prescribed burning and herbicides. *Natural Areas Journal* 18: (accepted) (Journal Series 11748).

Stumpf, Julie A., James Stubbendieck, Charles Butterfield, and Ronald D. Hiebert. 1998. An assessment of prairie restoration at two national monuments. *Natural Areas Journal* 18: (accepted) (Journal Series 11977).

Ortmann, John, Walter H. Schacht, James Stubbendieck, and Dennis Brink. 1998. The "Foilage is the Fruit" hypothesis: Complex adaptations in buffalograss (*Buchloe dactyloides*). *American Midland Naturalist* 115: (accepted) (Journal Series 11915).

Perez, Claudio J., Steven S. Waller, Lowell E. Moser, James Stubbendieck, and Alan A. Steuter. 1998. Seedbank characteristics of a Nebraska Sandhills Prairie. *Journal of Range Management* 51:55-62. (Journal series 10674).

Willson, Gary D., and James Stubbendieck. 1997. Fire effects on four growth stages of smooth brome. *Natural Areas Journal* 17:306-312. (Journal Series No.11250).

Stubbendieck, James, Jay B. Fitzgerald, Dale T. Lindgren, and Julia A. Lamphere. 1997. *Penstemon haydenii*: An endangered species. *Bulletin of the American Penstemon Society* 56:3-7 (Journal Series No. 10181).

Willson, Gary D., and James Stubbendieck. 1996. Suppression of smooth brome by atrazine, mowing, and fire. *The Prairie Naturalist* 28:13-20 (Journal Series No. 11251)

Schacht, Walter H., James Stubbendieck, Thomas B. Bragg, A. J. Smart, and J. W. Doran. 1996. Soil quality response of reestablished grasslands to mowing and burning. *Journal of Range Management* 49:458-463 (Journal Series No. 11044)

Stubbendieck, James, John Ortmann, Charles H. Butterfield, and Robert B. Mitchell. 1996. Leaf blower aids in prescribed burning of prairies (Nebraska). *Restoration and Management* 14:112-113 (Journal Series No. 11252)

Ortmann, John, James Stubbendieck, and Anne M. Parkhurst. 1995. Sources of variation in leaf moisture content of eastern redcedar. *Proceedings of the North American Prairie Conference* 14:31-34.

Willson, Gary D., and James Stubbendieck. 1995. Soil moisture and temperature differences between burned and unburned smooth brome- and big bluestem-dominated sites. *Proceedings of the North American Prairie Conference* 14:79-82.

Stubbendieck, James, Theresa R. Flessner, Charles H. Butterfield, and Alan A. Steuter. 1994. Establishment and survival of the endangered blowout penstemon. *Great Plains Research* 3:3-19.

Flessner, Theresa R., and James Stubbendieck. 1993. Pollination characteristics of blowout penstemon (*Penstemon haydenii* S. Wats.) *Transactions of the Nebraska Academy of Sciences* XIX:63-66.

Schmidt, Thomas L., and James Stubbendieck. 1993. Factors influencing eastern redcedar seedling survival on rangeland. *Journal of Range Management* 46:448-451.

NebGuides of a total of 10

Ortmann, John, Katherine L. Miles, James Stubbendieck, and Walter Schacht. 1997. Management of smooth sumac on grasslands. NebGuide G97-1319-A. 2 pages.

Ortmann, John, James Stubbendieck, George H. Pfeiffer, Robert A. Masters, and Walter H. Schacht. 1996. Management of eastern redcedar on grasslands. NebGuide G96-1308-A. 4 pages.

Case, Ronald M., James Stubbendieck, Scott E. Hygnstrom, and Dallas R. Virchow. 1996. Pocket gophers and their control. NebGuide G96-1290-A. 4 pages.

Book Chapters of a total of 7

Stubbendieck, James., and Thomas A. Jones. 1996. Other cool-season grasses, pages 765-780. In: *Cool-season forage grasses*. Agronomy Monograph 34. American Society of Agronomy, Madison, Wisconsin.

Stubbendieck, James. 1995. Rangeland plants.. *Encyclopedia of Agricultural Science* 3:559-574. Academic Press, San Diego.

Other

Stubbendieck, J., and Walter Schacht. 1997. *Rangeland Analysis: A laboratory manual for Agronomy 444/844*. 8th edition. University of Nebraska. 74 pages.

Stubbendieck, James, Julia A. Lamphere, and Jay B. Fitzgerald. 1997. Blowout penstemon - An endangered species. *NEBRASKAland* 75:6-page pullout brochure.

Hiebert, Ronald D., and James Stubbendieck. 1995. Handbook for ranking exotic plants for management and control, Natural Resources Report 08, National Park Service, U. S. Department of the Interior, Washington, D.C.; 42 pages.

Stumpf, Julie A., James Stubbendieck, and Charles H. Butterfield. 1995. *An assessment of exotic plants at Scotts Bluff National Monument and Effigy Mounds National Monument*. National Park Service, U. S. Department of the Interior, Washington, D.C.; 156 pages.

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Education

Ph.D. 1963 University of Illinois, Ecology.
M.S. 1959 Michigan State University, Zoology.
B.S. 1953 Michigan State University.

Professional Experience and Employment

1976- Professor, Kansas State University, Science Advisor, Environmental Protection, Atlantic Richfield Co., Los Angeles.
1968-1976 Associate Professor, Kansas State University.
1964 Naturalist, Shenandoah National Park, Virginia.
1963-1968 Assistant Professor, Kansas State University.

Research Interests

Avian population and community ecology with emphasis on grassland bird, bioenergetics.

Professional Memberships

1995 Board of Directors, Sutton Avian Research Center, Inc., Bartlesville, Oklahoma.
1991 Director, Kansas Breeding Bird Atlas Project.
1991 Steering committee, North American Ornithological Atlas Project.
1980 Advisory Board, Konza Prairie Research Natural Area.

Selected Publications (last 5 years)

Zimmerman, J.L. 1997. Avian community responses to fire, grazing, and drought in the tallgrass prairie. In *Ecology of Great Plains Vertebrates and their Habitat.* F.L Knopf and F.B. Samson, eds. Springer-Verlag.

Robel, R. J. Keating, J. Zimmerman, K. Behnkke, and K. Kemp. 1997. Consumption of colored and flavored food morsels by Harris' and American Tree Sparrows. *Wilson Bull.* 109:218-225.

Zimmerman, J.L. 1996. A comparison of water consumption between two grassland Emberizids breeding in mesic and arid habitats. *Prairie Nat.* 27:215-221.

Zimmerman, J.L. 1993. *The Birds of Konza: The avian ecology of the tallgrass prairie.* University Press of Kansas, Lawrence. xiii + 186 pp.

Zimmerman, J.L. 1992. Density-independent factors affecting the avian diversity of the tallgrass prairie community. *Wilson Bull.* 104:85-94.

Human, T.W., R.J. Robel, J.L. Zimmerman, and K.E. Kemp. 1992. Time budgets of confined northern cardinals and Harris' sparrows in flocks of different sizes and composition. *J. Field Ornithol.* 63:129-137.

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R.D. Hiebert, National Park Service

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